Efficacy of pulsed electromagnetic field on pain and nerve conduction velocity in patients with diabetic neuropathy

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Background
Diabetic peripheral neuropathy is one of the most common and disabling complication of diabetes mellitus.
Aim
The aim of this study was to investigate the effect of pulsed electromagnetic field (PEMF) on diabetic peripheral neuropathy.
Settings and design
A total of 30 patients with diabetic neuropathy from both sexes were selected from the Outpatient Clinic of Diabetes Mellitus, Faculty of Medicine, Cairo University, with age ranging from 40 to 50 years. They were divided into two equal groups: PEMF group (group A) and control group (group B).
Materials and methods
Group A received PEMF with frequency of 50 Hz and intensity of 20 G in addition to traditional physical therapy program. Group B received traditional physical therapy program only. The treatment program was conducted three times per week for 4 weeks. Measurements of pain intensity by visual analog scale and peroneal nerve conduction velocity by computerized electromyography device were done before and after treatment.
Results
Results revealed that there was a significant reduction of pain intensity and significant improvement of peroneal nerve conduction velocity (m/s) in both groups ($P<0.05$), with slightly in favor of group A.
Conclusion
It could be concluded that PEMF combined with traditional physical therapy program has a positive effect on diabetic neuropathy symptoms.

Keywords:
diabetic neuropathy, pain, peroneal nerve conduction velocity, pulsed electromagnetic field

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Introduction

Diabetic peripheral neuropathy (DPN) is the most common and troublesome complication of diabetes mellitus (DM), leading to the greatest morbidity and mortality and resulting in a huge economic burden for diabetes care [1]. Diabetic neuropathy should be suspected in any patient with type 1 diabetes with more than 5 years of duration and in all patients with type 2 diabetes [2].

The neuropathies developing in patients with diabetes are known to be heterogenous by their symptoms, pattern of neurologic involvement, course, risk covariates, pathologic alterations, and underlying mechanisms. Moreover, diabetic patients can develop chronic inflammatory demyelinating polyradiculopathy [3].

The vast majority of patients with clinical diabetic neuropathy have a distal symmetrical form of the disorder that progresses following a fiber length-dependent pattern, with sensory and autonomic manifestations predominating. This pattern of neuropathy is associated with a progressive distal axonopathy [4].

DPN is characterized by aberrant symptoms of stimulus-evoked pain including allodynia and hyperalgesia. It often leads to mood and sleep disturbance, and thus can substantially impair the quality and expectancy of life. However, beyond the careful management of the diabetes itself through glycemic control and pain relief for neuropathy [5], the patient cannot overcome all these complications.

Treating neuropathy is a difficult task for the physician, and most of the conventional pain medications primarily mask symptoms and have significant adverse effects and addiction profiles. Some physical modalities such as acupuncture,

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magnetic therapy, and yoga has been found to provide benefit. One of the approaches which is currently of clinical interest includes low-frequency pulsed magnetic fields (PEMFs), which have analgesic, neurostimulatory, trophic, and vasoactive actions [6].

Magnetic field therapy is considered an efficient modality in physical therapy for treatment of many pathological conditions, as it exhibits many activities such as vasodilatation, analgesic action, anti-inflammatory action, and antiedematous activity [7].

Previous studies suggested that PEMF therapy can decrease pain. To date, however, it remains difficult to determine whether the analgesic effect observed in patients is attributable to a direct effect of PEMF on pain or to an indirect effect of PEMF on inflammation and healing. In this study, it was found that PEMF does not directly influence heat pain perception in healthy individuals [8].

Although pulsed electromagnetic stimulation has been shown to enhance peripheral nerve regeneration, the effect of a magnetic field on nerve repair is less clear. One study was done on sheep to establish what effect an imposed magnetic field has on peripheral nerve regeneration after transection and repair. It was found that electromagnetic fields do not enhance peripheral nerve regeneration [9].

Data from cell culture, animal, and human studies suggest that exogenous application of weak, nonthermal electromagnetic fields upregulates nerve growth factor, insulin-like growth factor-1, insulin-like growth factor-2, fibroblast growth product, and vascular endothelial growth factor; reorients Schwann cells; enhances macrophage activity and endoneurial blood flow; reduces nociceptive afferent signal transduction; and reduces free radicals and oxidative stress. Thus, magnetic stimulation may be an appropriate noninvasive intervention that could reduce DPN symptoms and produce disease modification [10].

High level of evidence was synthesized regarding the lack of beneficial effects of physical resources such as low-level laser, ultrasound, and PEMF on pain, function or range of motion in the treatment of pain [11].

So, the aim of the study was to investigate the effect of PEMF on pain and motor nerve conduction velocity (NCV) in patients with diabetic neuropathy.

Patients and methods

Patients

A total of 30 patients (13 males and 17 females), with their ages ranging from 40 to 50 years, presented clinically and referred by physician with DPN, participated in this study. The patients were selected according to the following criteria: all patients have type 2 DM with symptoms and signs of mild peripheral neuropathy, patients with mild (grade 1) peripheral neuropathy according to grading of neuropathy scale [12]. The measurements were done to the dominant limb, and duration of illness was more than 5 years. The BMI was less than 30 kg/m^2. Patients were excluded if they had peripheral vascular diseases as varicose veins or deep venous thrombosis, obesity (BMI$>$30 kg/m^2), sever sensorimotor or autonomic neuropathy, acute nerve root compression (radiculopathy) affecting lower limbs, previous neurological problems as spinal cord injury or stroke, presence of internal fixation, and pregnancy.

Design of the study

Nonrandomized controlled trial was conducted. It was approved by the Ethical Committee of the Faculty of Physical Therapy, Cairo University. All patients were requested to sign a written informed consent before starting the study. The patients were assigned to one of the following two groups: group A included 15 patients (seven males and eight females) with DPN who received PEMF in addition to selected physical therapy program and group B also included 15 patients (six males and nine females) with DPN but they underwent only selected physical therapy program.

Evaluation procedures

Each participants underwent the same evaluation, which was performed by the same therapist at the beginning and end of the treatment period (4 weeks). All participants were asked to maintain their activity levels during the period of the study. Evaluation procedures included the following:

(1) The measurement of pain severity: the intensity of pain was evaluated by using visual analog scale (VAS). Each patient was asked to mark and score on a line at the point that represents his or her intensity of pain on a 10-cm scale, in which 0 represents 'no pain' and 10 represents 'worst pain'.
(2) The measurement of peroneal NCV: the NCV of the common peroneal nerve (m/s) was measured by using Computerized Electromyography Tonnies Neuroscreen Plus Version 1.59 (1998; Erich Jaeger GmbH, Hoechberg, Germany).

Procedure of nerve conduction velocity measurement

The patients were positioned supine. An active electrode was placed over the midpoint of the extensor digitorum brevis muscle on the dorsum of the foot. Reference electrode was placed slightly distal to the fifth metatarsophalangeal joint. Ground electrode placement was over the dorsum of the foot. Stimulation point 1 (S1): the cathode was placed 10 cm proximal to the active electrode, slightly lateral to the tibialis anterior tendon. Stimulation point 2 (S2): the cathode was slightly posterior and inferior to the fibular head (Fig. 1). The anode was proximal. Pulse duration of 0.2 ms at the rate of 1/s at supramaximal intensity was used for conduction studies. The distance between S1 and S2 was measured by tap measurement and entered into the computerized electromyography device. The device automatically calculates the motor conduction velocity.

Treatment procedures

The treatment procedures were in the form of PEMF and exercise. The treatment was applied three times/week for 4 weeks.

(1) PEMF (ASA Easy terza series; Italy) was used in the treatment of group A only. Each patient was placed in a comfortable relaxed position (supine position). The appliance was connected to electrical mains supplying 230 V. The solenoid was adjusted to be over the lower limb, with frequency of 50 Hz and intensity of 20 G for 20 min. Treatment was conducted for 4 weeks, three times per week, day after day [13].
(2) Exercises program for DPN:

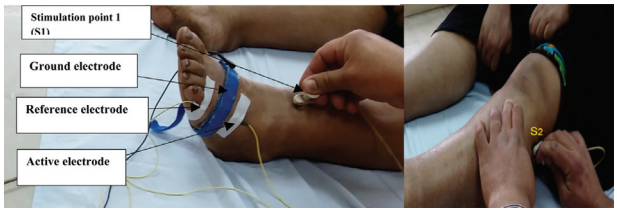
Selected physical therapy programs for all patients in both groups were done at the outpatient clinic of Faculty of Physical Therapy, Cairo University, plus home exercises routine.

Proprioception exercises

All the proprioception exercises were performed for a duration of 30 min with repetition 10 times for every exercise for 12 sessions, which was every other day plus home routine. The exercises started with static balance activities and progressed to dynamic balance activities:

(1) They were started with static balance activities by using the balance board from standing position. Each patient was instructed to move the board forward, backward, and from side to side using both feet. The exercise was done with open eyes and support (hand rail) firstly, and then patients were asked to close their eyes with removal of any support. Also, patients in both groups were asked to stand on a level floor surface with one foot in front of the other and arms beside the body. The patient was standing in this position for 30 s with his/her eyes opened and then with eyes closed.
(2) After several repetitions of static balance exercises, the patients began dynamic balance activities by walking on different surfaces, as patients trained gradually to walk on hard, then on flat floor, and then progressed to uneven surface. Each patient climbed stairs up and down, and finally, got up from a standard chair (four times) without arm support.

Figure 1



Electrodes placement and simulation sites for common peroneal nerve conduction velocity study.

Range of motion exercises [14]

Active free range of motion exercises for ankle and subtalar joints were done for 30 min plus home routine. The patients were instructed to perform the exercises ten times for each movement:

(1) Active dorsiflexion and plantar flexion of the metatarsophalangeal joints holed each direction for 10 s.
(2) Active dorsiflexion and plantar flexion of the ankle joint holed each direction for 10 s.
(3) Active supination and pronation of the subtalar joints holed each direction for 10 s.

Statistical analysis

Descriptive statistics (mean±SD) was used for all participants in all groups to study all variables. Independent *t*-test was used to compare the pretreatment and post-treatment NCV variables between the two groups of the study. Paired *t*-test was used to compare the before and after treatment results in the same group for NCV variables. Wilcoxon's test and Mann–Whitney *U*-test were used to analyze the VAS data. *P* value less than 0.05 was considered statistically significant.

Results

None of the patients in either treatment groups dropped out throughout the study period. There was

no significant difference ($P>0.05$) between both groups regarding demographic data (Table 1). Sex distribution was illustrated in Fig. 2.

Wilcoxon's test was used to test the differences between the preintervention and postintervention values in the same group for VAS values. As shown in Table 2, there was a significant difference ($P>0.05$) between pretreatment and post-treatment mean values in groups A and B, as pretreatment mean value was 4.25±1.14 and 4.5±0.9, respectively, whereas that of post-treatment was 1.42±0.9 and 3.75±1.66, respectively. According to Wilcoxon's test, *z*-value was 3.998 and percentage of improvement was 28.57%. The Mann–Whitney *U*-test was performed to test the differences between the post-treatment values of VAS for both groups. As shown in Table 3, there was a significant difference ($P<0.05$) between both groups regarding post-treatment values, as was revealed in favor of group A, as the mean±SD were 1.42±0.9 and 3.75±1.66, respectively, and Mann–Whitney *U* value was 96.4.

There was a significant difference ($P>0.05$) between pretreatment and post-treatment mean values of peroneal NCV in groups A and B (Table 4), as pretreatment mean values were 32.69±1.99 and 32.94±2.41, respectively, whereas post-treatment values were 47.34±4.3 and 3.56±3.56, respectively. As shown in Table 5, there was a significant difference ($P<0.05$) in post-treatment values, as was observed in favor of group A, as the mean±SD were 47.343±4.304 and 43.973±3.566, respectively.

Discussion

DPN affects almost 50% of patients with chronic type 2 diabetes [15]. It is generally considered to be one of

Table 1 Demographic data of the participants in both groups

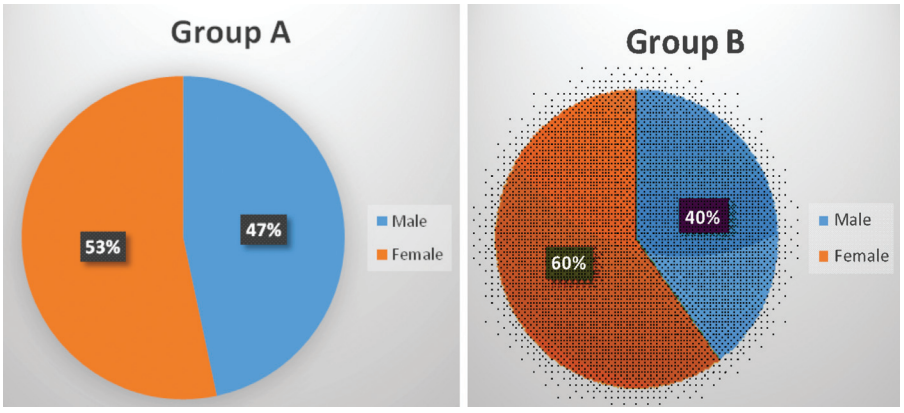
	Groups	Mean±SD	*P* value	Level of significance
Age (years)	Group A	44.13±2.669	0.291	NS
	Group B	45.13±2.416		
BMI (kg/cm^2)	Group A	27.99±1.39	0.114	NS
	Group B	28.8±1.3		
Duration of illness (years)	Group A	10.8±2.11	0.421	NS
	Group B	10.13±2.35		

Table 2 Wilcoxon's test between the preintervention and postintervention values in the same group

VAS	Group A		Group B	
	Pretreatment	Post-treatment	Pretreatment	Post-treatment
Mean±SD	4.25±1.14	1.42±0. 9	4.5±0.9	3.75±1.66
% of improvement	43.8		28.57	
z-Value	3.116		3.998	
P value	0.001		0.001	
Level of significance	S		S	

S, significant; VAS, visual analog scale.

Figure 2



Sex distribution.

Table 3 Mann–Whitney test between the post-treatment values for both groups

	Groups	Mean±SD	Mann–Whitney *U* value	*P* value	Level of significance
VAS	Group A	1.42±0.9	96.4	0.001	S
	Group B	3.75±1.66			

S, significant; VAS, visual analog scale.

Table 4 Paired *t*-test for peroneal nerve conduction velocity values before and after treatment in groups A and B

Peroneal NCV (m/s)	Group A		Group B	
	Before treatment	After treatment	Before treatment	After treatment
Mean±SD	32.69±1.99	47.343±4.3	32.94±2.41	43.97±3.56
% of improvement	44.81		33.49	
P value	0.001		0.001	
Level of significance	S		S	

NCV, nerve conduction velocity; S, significant.

Table 5 Unpaired *t*-test for peroneal nerve conduction velocity between post-treatment values for both groups

	Groups	Mean±SD	*P* value	Level of significance
NCV	Group A	47.343±4.304	0.027	S
	Group B	43.973±3.566		

NCV, nerve conduction velocity; S, significant.

the most common complications of DM, affecting both types of diabetes equally. Approximately 30% of patients with DM are affected by DPN [16,17].

Previous studies had reported that PEMFs are able to modify some parameters of nerve function in diabetic patients and can stimulate nerve growth, regeneration, and functional recovery of nerves in cells in animal models with nerve disease [10,18].

The present study aimed to investigate the effect of PEMF with intensity of 20 G and frequency of 10 Hz for 20 min/session three times per week for 4 weeks on pain intensity and NCV of peroneal nerve in patients with DPN.

The present study showed that there was a significant improvement regarding all variables of both groups A and B in favor of group A, as *P* value was less than 0.05.

These findings were in line with those of Lei *et al.* [19] who investigated the therapeutic potential of PEMF in relieving peripheral neuropathic symptoms in diabetic rats. The results demonstrated that treatment with PEMF might prevent the development of abnormalities observed in animal models for DPN. It is suggested that PEMF might have direct corrective effects on injured nerves and would be a potentially promising noninvasive therapeutic tool for the treatment of DPN.

Application of PEMF facilitates regression of the main clinical symptoms of DPN, improves the conductive function of peripheral nerves, improves the state of 1a afferents, and improves the reflex excitability of functionally diverse motor neurons in the spinal cord. This explanation is supported by Musaev *et al.* [20] who performed a clinical and electro neuromyographic study in 121 patients with diabetic polyneuropathy before and after the courses of treatment with PEMFs at different frequencies (100 and 10 Hz). The study concluded that PEMF at 10 Hz was found to have therapeutic efficacy, especially in the initial stages of DPN and in patients with DM for up to 10 years.

The reduction of pain intensity was better after treatment of PEMF, and this result is in agreement with Morki and Sinaki [21] who postulated that magnetic therapy has become one of the most rapidly emerging alternative therapies where magnets have been promoted for their analgesic and energizing effects with no adverse effects unlike drugs. The analgesic effect of PEMF therapy could be attributed to the physiologic mechanisms of pain relief, which may be owing to presynaptic inhibition or decreased excitability of pain fibers [22].

Moreover, PEMF can modulate the action of hormones, antibodies, and neurotransmitter surface receptor sites of a variety of cell types. This may cause changes in transfer rate of electrons during the electron exchange between single molecules that may either slow down or accelerate chemical reactions [23].

Similarly, pain reduction by PEMF results from the cell membrane to be lowered to hyperpolarization level

of about −90 mV, and so it blocks the pain signal transmission. Magnetic field also influences ATP production, increases the supply of oxygen and nutrients through the vascular system, improves the removal of waste metabolites through lymphatic system, and helps to rebalance the distribution of ions across the cell membrane thus reducing pain and muscle spasm [24].

>The findings of the study are in agreement with those of Chebotar'ova and Chebotar'ov [25] who performed clinical and electroneuromyography tests for objective evaluation of low-power electromagnetic therapy effectiveness in 12 patients with diabetic polyneuropathies. It is established that low-power electromagnetic therapy gives the stable positive effects. The positive changes were confirmed by the decrease of neurological deficit and required insulin daily dose, NCV increase, and increase of the muscle compound action potentials (muscle power) and peripheral outflow in some patients.

Conclusion

From this study, it could be concluded that both traditional physiotherapy alone and PEMF combined with traditional physiotherapy are effective in improving diabetic neuropathy symptoms, with superior effects with combining PEMF and traditional physiotherapy. The results should be limited to short-term outcomes to PEMF.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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